Segmentation of Facade Images using Ultimate Opening

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1. INTRODUCTION

In recent years, automatic reconstruction, modeling and interpretation of urban environment and building structures is an area which gained interest. Urban environment's modeling allows developing different applications such as: cultural and tourism information, urban planning, simulation for urban catastrophes, business development, and virtual reality. Five levels of detail (LoD) have been defined by the Sig3D group for urban environments models [1]. Several approaches of modeling have focused on coarse modeling, for instance: polyhedral representation, main walls, roof planes and ground planes. Nevertheless, the last research issues try analyzing facades of buildings. This analysis extracts and reconstructs windows, doors and ornaments to provide rich information of the buildings adding realism for visualization.

Our goal is the automation of the façades interpretation from images; especially to detection/extraction structural objects mainly windows. We propose connected-component (CC) segmentation to detect of facade structures. The segmentation is based on a morphological operator named ultimate opening.

This paper is organized as follows. Section 2 presents the related work about urban environment's modeling particularly on façade modeling and windows detection. In Section 3, some basic concepts of ultimate opening are presented and we describe our application. In the Section 4, the results are shown and the advantage of our method is presented. Finally, conclusions are drawn in Section 5.

2. RELATED WORK

Urban environment's modeling has been studied by different lines of research. First approaches are based on computer vision, where façade modeling works without semantic information about objects such as windows or doors; they present a photorealism of façade meshes or coarse model of building taking into account different combinations of input data such as: 2D or 3D or/and fixed or vehicle laser scans (LIDAR), ground level image, (airborne, satellite) aerial images [2, 3]. Other approaches are focused on façade images interpretation such as: model-based façade reconstruction techniques [4, 5, 6], grammar urban modeling approaches [7, 8] and Markov Chain Monte Carlo sampler (MCMCs) approaches to exploit grammar information considering a probability distribution function [9, 10]. Some of these approaches require calibrated façade texture, regular structures, or 3D associated information to detect façade structures. Also, they do not support vegetation and occlusions problems.

Our work is focused on a segmentation procedure behind the structures identification to facilitate the semantic/grammatical information extraction when facades images do not have all assumptions required (ortho-rectified input images, horizontal and vertical regularities, highly symmetric and repeated structures).

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3. ULTIMATE ATTRIBUTE OPENING (UAO)

Ultimate opening (UO) , closing by duality, has been introduced by Beucher in [11]. This is a non-parametrical method and a non-linear scale-space based on morphological numerical residue to extract connected components (CCs). Retornaz and Marcotegui have extended and implemented ultimate attribute opening [12]. Two applications have been developed using UO: Image analysis to measure of granulometry of rocks [13] and automatic localization of text [14].

3.1. Basic Notions

3.1.1. Ultimate Opening

The ultimate opening θ analyses the difference between two consecutive openings. This operator has two significant outputs for each pixel x from an input image I: the maximal difference between openings (Residue, $R_\theta(I)$), the opening size when the maximal residue has been generated ($q_\theta(x)$). The equations describing the evolution of UO can be written as:

$$\begin{aligned} R_\theta\left(I\right) = sup\left(r_\lambda\left(I\right)\right), \quad & \forall\lambda \geq 1 \\ \text{with} \quad & r_\lambda\left(I\right) = \gamma_\lambda - \gamma_{\lambda+1} \\ q_\theta\left(x\right) = max\left(\lambda\right) : \lambda \geq 1, \quad & r_\lambda\left(x\right) = R_\theta\left(x\right) et > 0 \end{aligned} \tag{1}$$

where, γ_λ is an opening of size λ.

3.1.2. Attribute Opening

A binary attribute opening in X consists in an opening by reconstruction associated to a given increasing criterion κ of each CC. This opening uses the criterion to keep or discard a CC. Gray attribute opening γ_κ can be defined as follows:

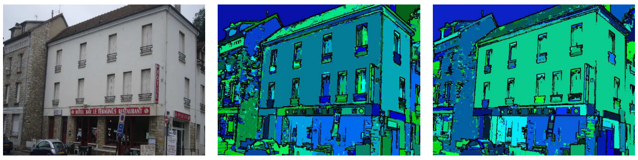
$$\left(\gamma_\kappa\left(f\right)\right)(x) = \max\left(h \middle| x \in \Gamma_k\left(X_h\left(f\right)\right)\right) \tag{2}$$

where, $X_h\left(f\right)$ is a gray scale image defined by threshold h of images, and Γ_k is a binary attribute opening.

3.2. Application on Façade Images

Different attributes can be utilized for the UAO. For the façade structures detection, height, or width of the CCs' bounding box are analyzed attributes. Fig. 1 shows two examples of UAO using a color gradient and testing both attributes. In first example with height attribute (Fig. 1(b)), more building pixels have been merged in one region because the contrast between sky and building façade is bigger than the contrast between wall and internal structures. On the other hand, with width attribute (Fig. 1(c)), the operator shows a better segmentation of façade structures. However, in second example (Fig.1(d)) the situation is vice versa, i.e. height attribute shows better segmentation than width attribute.

(a) Original Image (b) $q_\theta\ (x)$ Height (c) $q_\theta\ (x)$ Width

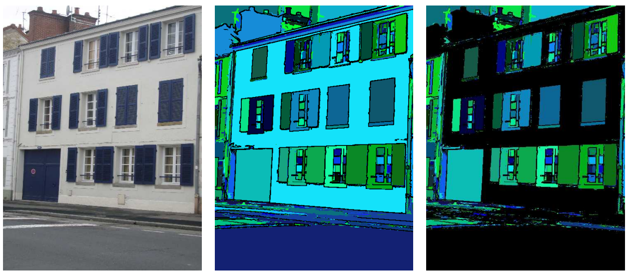


(d) Original Image (e) $q_\theta\ (x)$ Height (f) $q_\theta\ (x)$ Width

Fig. 1. Example UAO: $q_\theta\ (x)$ is randomize value

4. EXPERIMENTAL RESULTS

In order to test our method, we have used two internet public databases (ZuBuD, TSG-60) and two own databases (Paris, Fontainebleau). To estimate the advantage of a pre-segmentation behind façade interpretation, we have extracted the features after the segmentation of each CC and we have eliminated some of them using two simple criteria. Fig. 2 shows the results obtained by the presented approach using simple criteria. We show all database tests on the following web site *http://cmm.ensmp.fr/∼hernandez/results/testsegmentationOU.htm*.



(a) Original Image (b) $q_\theta\ (x)$ Height (c) $CC_H < I_H/2$ and $CC_W < I_W/3$

Fig. 2. Simple criteria application

5. CONCLUSIONS AND FUTURE WORK

In this paper we present an application of ultimate attribute opening to segment façade images. The utilization of width and height attributes presents good results, but we could not choose one of them for all test. Thus, we will analyze a possible combination such as ultimate multi-attribute opening. Also, we showed how our approach by connected component could help the process of structures extraction from façade images. This is the first step in a semantic detection process. We intend to apply a machine learning process using region features (shape and color descriptors) to classify regions.

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